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ABSTRACT

Selection and specification of a minicomputer time-sharing system to extend computer facilities for large scale computer-based instruction projects at the University of Texas at Austin are described. Two and a half years of implementation and operating experience are summarized followed by seven specific course applications of the minicomputer. Operating costs for the minicomputer and detailed and personnel requirements and functions are described for this system. The user subroutine and the usage accounting system are appended. (Author/CH)

SELECTION AND OPERATION OF A MINI-COMPUTER TIME-SHARE SYSTEM FOR A UNIVERSITY

EP-39/8/4/75

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ABSTRACT

This report summarizes the selection and operation of a mini-computer time-share system by Project C-BE at The University of Texas at Austin. It is intended as both a report on two and one-half years of operating experience and to provide information useful to others who are considering installation of new time-sharing computer systems. Conclusions and recommendations regarding system operation are included.

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Selection and Operation of a Mini-Computer Time-Share System for a University

Introduction

Project C-BE is a four-year project which began in September 1971, and has received $1.63 million in grants from the National Science Foundation, plus sizable matching funding from The University of Texas at Austin. Under the co-direction of Dr. John J. Allan III, Associate Professor of Mechanical Engineering, and of Computer Sciences, and Dr. J. J. Lagowski, Professor of Chemistry and of Education, the Project has as its objective "to study the effects of computer-based instruction at a typical large university."

Approximately thirty professors in many fields, including such areas as engineering, chemistry, psychology, English, mathematics, physics, zoology, economics, linguistics, home economics, architecture, and biology are participating in the research by developing and implementing computer-based courses. The Central Staff members of PROJECT C-BE, by observing, advising and assisting these professors, are attempting to discover the procedures which are most effective for a variety of teaching styles and subject areas.

At the time of research initiation computer facilities at U.T. were rather well developed and included: (1) a large CDC 6600/6400 dual processor system with extensive peripherals, (2) a Sigma V, and SDS 930/AD4 complex which was operated as either a hybrid system or as stand-alone machines, (3) IBM 1500 system for CAI and, (4) many mini-computer systems used for research. These computer facilities served the computational needs for instructional and research computing. Another large IBM 370 system provided administrative computing to the campus of 40,000 students.

Projected Computing Requirements

The original proposal to NSF called for research involving the following

types of computer applications:

1. Tutorial interaction through student terminals linked to time-sharing computer systems. Terminal types to include interactive graphics as well as alpha-numeric output.
2. Real time monitoring and control of laboratory experiments including data acquisition, processing, storage and analysis.
3. Interactive laboratory simulation.
4. On-line data base for student records and exam administration.

Planning for support of these applications indicated a large increase in demand for interactive terminals. As curricular materials were developed and put into production the following terminals loads would be anticipated:

Within 6 months of project funding	12 terminals
Within 12 months	36 terminals
Within 24 months	48 terminals
Peak requirement	56 terminals

In addition to increased volume the project specified other interactive requirements:

1. Response time at interactive terminals of less than three seconds.
2. Improved reliability which will allow scheduling of students at terminals with high probability of successfully finishing the assignment.
3. Selectable data rates of 110, 300, or 1200 baud. The high baud rates are necessary to effectively use computer graphics and to output tutorial material with a significant amount of text or graphics.
4. Easy access to on-line storage to permit record keeping and data-base manipulation.

Based upon earlier experiences with interactive tutorial programs at U.T., typical core requirements were estimated to be 60K bytes per

user. This size would provide approximately thirty minutes of interaction, assumed modules were core resident. Interactive programs had been developed in a local authoring language, CLIC, and it was anticipated that future development would continue in this language so that any new computer should be compatible with the language.

Proposed Facilities

With these general specifications formulated, Project personnel asked the Computation Center to specify hardware and software enhancements which would be necessary to provide the service. The alternatives considered were as follows:

1. Augment existing systems
   (a) CDC 6600/6400 system
   (b) SIGMA V system
   (c) IBM 1500 system
   (d) NOVA system at Applied Research Laboratory
2. Purchase terminal time from outside source.
3. Acquire a new stand-alone system.
   (a) Medium scale computer
   (b) Mini-computer

Augmentation of existing systems was the first alternative considered. The CDC system offered the most potential for expansion and, in fact, extensive expansion plans were well advanced before the Project C-BE grant was approved. During the time the grant was being negotiated, the University installed the CDC 6400 main frame and increased the disc storage capacity. Plans were formulated for a front end communication processor and the purchasing cycle was begun. All of these plans however could not provide sufficient interactive terminal support in the time frame proposed. Problems were also anticipated with response time and system stability. Stability and reliability problems were anticipated because the system software was being developed and debugged during the time when C-BE would be needing the system.

The University-owned Sigma V computer was considered for expansion into a 64 port time share system. This proposal proved to be very expensive because there was very little hardware or software to start with, and the Sigma V is not particularly well suited for the purpose.

Expansion of the IBM 1500 system also proved not to be feasible. Some of the reasons were: (1) low throughput, (2) poor software support, (3) no remote terminal facilities, (4) obsolete technology, and (5) a very high cost per terminal hour.

The Petroleum Engineering Department operated a Super NOVA system at the Applied Research Laboratory. Excess time was available on the machine and the possibility was explored to install a multiplexer to support sixteen time-share ports. Approximately $15,000 of additional equipment would be required and either leased line or dial service communications would be used. Leased lines were considered; however, because of the distance of 7 1/2 miles the cost would be $496 per month for 16 lines. Dial phones at the computer end alone would have cost $692 per month and each terminal would also have to have a dial phone. These costs were considered too high to be feasible.

Having explored the expansion potential and finding problems with each proposed route the directors investigated the purchase of terminal time from a service company. Because of the distance from the service center and other factors, the cost appeared to be unreasonably high (estimated to be $1,000 per month per port for 24 hour service). For C-BE materials to become viable teaching tools, cost effectiveness was considered to be very important.

The acquisition of a new stand-alone computer system was considered as the final alternative. With the assistance of personnel from the Computation Center a set of performance specifications was drawn up for a medium scale computer system to be dedicated to instructional computing. Detailed proposals were received from these vendors: Digital Equipment Corporation, Xerox, and IBM. The proposed systems would cost in the range of $600 to $800 thousand and would require approximately $50,000 annual operating expenses. Such a system would initially provide 64

ports for time-share and would be expandable to 128 ports. Multiple languages could be processed and a significant amount of computing power would be available for background batch processing.

While this alternative would probably be feasible for the long range support of computer-based education at U. T. Austin, Project C-BE did not have the financial support to proceed. (The University has since purchased a PDP 10 system to be used for instructional computing.)

Real-time monitoring of laboratory experiments as proposed requires a mini-computer data acquisition system available for use in the laboratory. No such equipment existed in undergraduate labs; however, many research facilities had mini-computers. In order to make the computer an integral part of laboratory courses, a significant amount of machine time would be necessary for development and instructional use. Since the only apparent solution to the real-time requirements for use in laboratories was a mini-computer, the proposal was made to acquire a mini-computer time-share system also.

Mini-computer specifications were developed from the general performance requirements of: (1) high reliability, (2) software availability, (3) vendor support, and (4) compatibility with existing U.T. owned equipment. Prospective vendors were requested to submit proposals on three separate mini-computer systems with the following characteristics:

A. Two (2) data acquisition systems, each containing 8K core memory, 16 analog-to-digital input channels, 6 digital-to-analog output channels, 2 serial ASCII interfaces, console and real-time clock. Software must include real-time BASIC as well as a full range of utility software.

B. One (1) time-sharing system capable of supporting a minimum of 16 simultaneous interactive BASIC users. Maximum response time was to be three seconds when all terminals are running typical tutorial programs. Disc storage space for program storage. Vendor supplied software must include time-shared BASIC and all necessary utility programs.

Specifications for equipment from the following companies were reviewed: Digital Equipment Corporation, General Automation, Raytheon Data Systems, Xerox Data Systems, Data General Corporation, Hewlett-Packard, DECISION, Educational Data Systems, Interdata, Microdata, and Control Data Corporation. Many of these vendors could supply equipment which would satisfy part of the requirements; however, a policy decision was made to acquire the three systems from a single supplier. This was based upon the factors of interchangeability of components for on-site maintenance ease and the advantage of having a sole source responsible for all warranties, hardware and software.

Purchased Equipment Specification and Operation

The equipment purchased from the low bidder, Data General Corporation, was as follows:

Two (2) Data Acquisition Systems consisting of NOVA 820 (2) computer with 8K of 800 ns. core memory, real-time clock, ASR33 teletype, two 1200 baud serial interfaces, 16 channels of 10-bit analog-to-digital input (expandable to 256 channels), 6 channels of 10-bit digital-to-analog output (maximum 24 channels). Cost: $15,900 each.

One (1) time-sharing computer system consisting of NOVA 820 computer with 24K of 800 ns. memory, real-time clock, ASR33 teletype console, high-speed paper tape reader and punch, 20 port communications multiplexer with baud rate selectable from 75 to 9600 baud, 2.494 million word moving head disc drive, and 256K work fixed head disc drive. Cost: $50,000.

The equipment was delivered during November 1972 with original installation and checkout performed by Data General Field Service and Applications Engineers. Hardware and software checkout of the data acquisition systems proceeded without difficulty, and the systems have been operational since that time with only normal maintenance problems encountered. Special purpose assembly language subroutines were written to provide real-time data-acquisition and process control using Single User BASIC. This language provides the system user a very simple and fast programming method. Time-sharing system development required much

more effort and time to bring the system into full production. A chronological listing of software development, and operating problems and characteristics follows.

November 1972 to December 1973

Data general Extended Time-Shared Swapping BASIC Rev. 0 [3] with Disc Operating System (DOS) [4] was run. This was the first release of the BASIC system and consequently, it had some errors and deficiencies which needed to be corrected. Data General was very good about correcting errors and other installations were able to use the software as maintained by Data General with smaller systems. Project C-BE, however, had additional requirements, and therefore undertook to make extensions to the system. The main modifications made were:

1. To provide 8-bit binary input and output to support the graphics operating system being developed for the Imlac Model PDS-1 graphics terminal.
2. To provide three levels of file access to BASIC users, i.e., private files, class files, and public files. This was necessary to allow CAI recordkeeping.
3. To provide a limited access system which prevented designated users access to certain commands such as LIST, DELETE. This gave security for CAI programs by preventing student users from obtaining listings.
4. To provide binary disc file read and write capability. This permitted the storage and retrieval of memory dumps from remote mini-computers in a much more efficient form.

The local modifications introduced new errors into the system and also relieved the vendor of some of the system responsibility because he could now say that the problems were caused by us. The system performance was very satisfactory; however, reliability was low. The most damaging error was the overwriting of disc files by the system. As the volume of disc files increased with prolonged use these errors increased until the disc had to be cleared and reloaded. This was particularly annoying and time consuming for CAI authors. Consequently, little tutorial material was installed on the system during this period.

January 1974 to August 1974

The newly released Extended BASIC Revision 3 operating with Real-Time Disc Operating System (RDOS) was installed in January and ultimately debugged to provide high reliability in March. This system provided most of the enhancements to BASIC needed for CAI and a much-improved file system. The decision was made to modify the Imlac Graphics system to use only ASCII characters for communication with the time-sharing system. This eliminated the need to make extensive modifications to BASIC to communicate in binary.

The new system required more memory, thus reducing user space available. In order to maintain 10,000 bytes of user space, the total number of active user ports was reduced to 18, since each port requires approximately 500 bytes of storage for input-output buffer and status tables.

After April 1, 1974, when the system was made reliable, extensive use was made of the system by students from Physics, Statistics, Linguistics, Mechanical Engineering, English, and General Business. Also, authors from Chemistry, English, Linguistics and Mechanical Engineering used the system. Anticipating increased demand for interactive BASIC terminals, C-BE formulated plans to expand the system to provide 32 ports.

September 1974 to December 1974

BASIC Revision 3.5 and Mapped Real-Time Disc Operating System Revision 3.02 (MRDOS) were installed after the hardware was expanded to 56K of memory in a NOVA 840. An additional 12 ports were installed in the communications multiplexer, making a total of 32 ports. A minimal number of patches have been required in this software.

The MRDOS system allows for foreground/background processing with a maximum of 31K words of memory assigned to a job. Normal operation runs BASIC in foreground with top priority, leaving a 9K memory partition in background to do disc management, assemblies, FORTRAN, ALGOL, special applications programs.

During prime hours, the system regularly supported 18 to 22 users with satisfactory response time. Accounting records were kept for approximately 55 days during the period with the system accumulating 4600 hours of terminal use time. Of these hours, 3,415 were used by 936 students in Chemistry, Physics, Mechanical Engineering, Linguistics and General Business. The remaining hours were accumulated by authors, system programmers, and miscellaneous users.

There were no hardware problems during this period which caused system downtime. Software errors caused one or two system crashes per week, which resulted in the loss of active jobs and required users to login again. These restarts usually resulted in approximately ten minutes of downtime per occurrence. Disc storage became very full and it was necessary to eliminate unneeded files regularly. This was done by issuing messages for users to delete extra files and by running a program in the background which either flags or deletes files which have not been accessed since an operator specified date. By these means disc space was kept 90% to 95% full.

A small number of user subroutines were added to the system to provide certain enhancements to the BASIC language and to reduce processing time for some frequently used operations. These assembly language subroutines are accessed by the "CALL" statement in BASIC. Use of special subroutines is kept to a minimum to improve transferability of programs to other systems. See Appendix A for documentation of user subroutines.

January 1975 to May 1975

Time-Shared BASIC Revision 3.6 (5) and MRDOS Revision 3.02 (6) were installed. The main change between Revision 3.5 and 3.6 is a revised task schedule which is designed to improve throughput. Hardware downtime has been a total of two hours during the period. This was a scheduled downtime to adjust the papertape reader. Downtime due to software failure averaged approximately once a week with restart time of less than ten minutes. Certain minimal changes have been made to BASIC and MRDOS to improve reliability. Each user is restricted to a maximum

core space of 10K bytes of combined program and data. This appears to be sufficient in most cases.

During the Spring, 1975 semester, the system operated very reliably and provided service to approximately 1600 users at 32 ports. Approximately 10,000 terminal hours were logged on the system during the period. Service was available 24 hours per day, seven days per week; however, as could be expected, most students wanted access weekday afternoons. Consequently there is a terminal shortage during prime hours and many idle terminals at other times. Peak load occurs between 1:00 and 3:00 p.m. with normal loading extending from 9:00 a.m. to 10:00 p.m. See Figure 1 for detail usage per hour. Only 6.8% of the total usage occured on the weekends. This usage pattern could be anticipated because the system was used primarily for undergraduate instruction and sufficient terminals were available to handle the needs during prime hours. Although the peak average usage is 12 terminals, there were many days when assignments were due that over 24 terminals were in use. The largest number observed in simultaneous use was 30 terminals.

Mapped RDOS is a multi-tasking operating system which provides foreground/background capabilities. BASIC was run in foreground with highest priority while background was used for disc management and assembly of programs for other NOVA computers. A test program to measure the amount of time available to the background was developed late in the semester when usage had dropped; therefore, no data is available for more than sixteen simultaneous user on-line. Sixteen users on-line utilizing a typical job mix left approximately 50% of cpu time available for background use. The operating system and other software provided by Data General Corporation will support batch processing in the background. This facility could provide a significant through put of jobs from a card reader and give a small school most of the instructional computation capacity required.

Vendor software provides an access security system requiring unique account numbers for each identifiable user and also maintains a record of system usage. PROJECT personnel have developed programs to assign

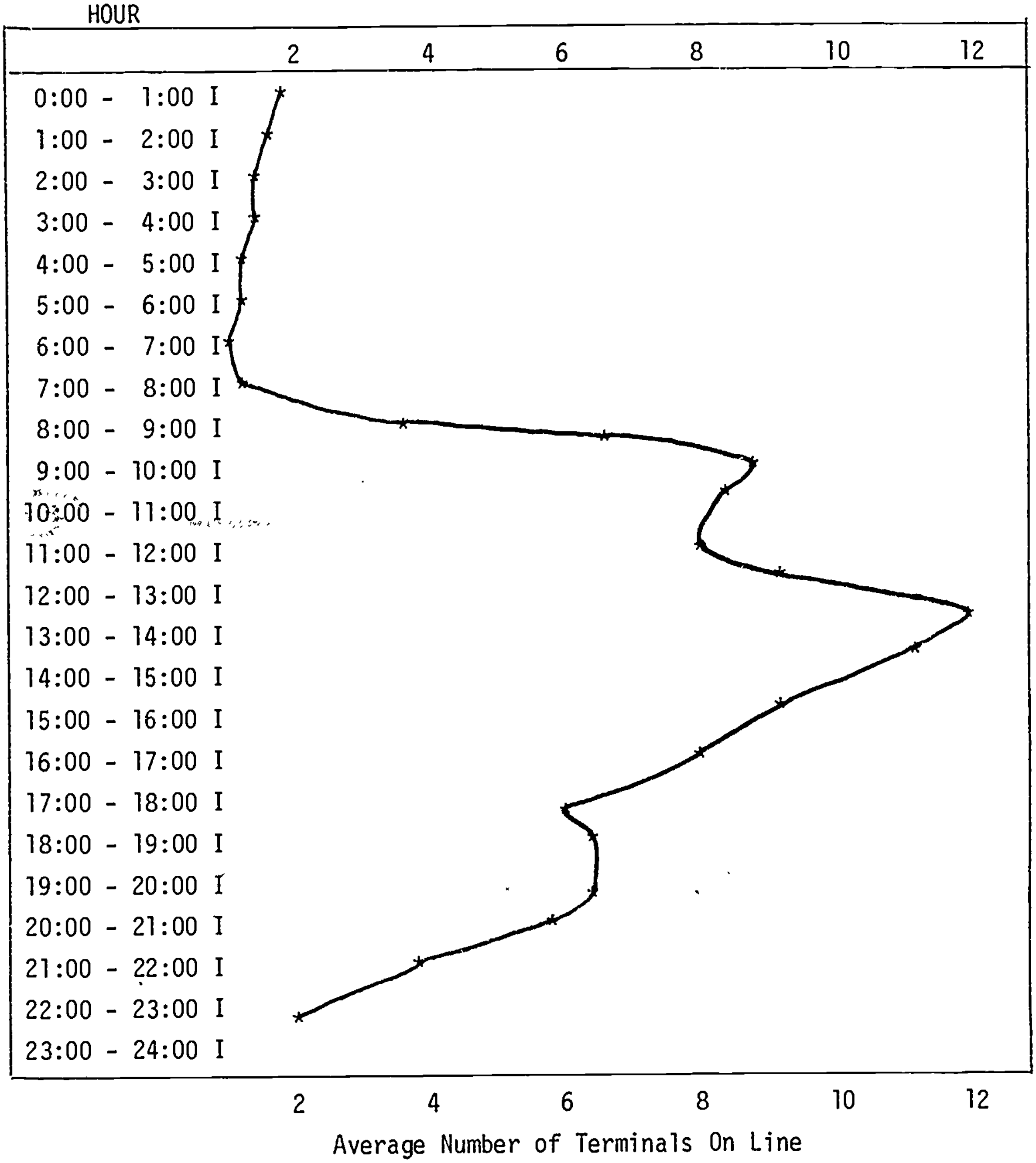

FIGURE 1.

Terminal Usage by Hour of the Day for Spring '75 Semester

account numbers, and process system accounting records to maintain usage records by user, hour of the day, day of the week, day of the month, and by port numbers. See Appendix B for details of system.

Applications

The major instructional uses of the NOVA time-share system included tutorial, computer-aided instruction (CAI), problem solving, simulation, and the teaching of programming. The following is a summary of the principal applications:

Chemistry - A series of programs administers a pre-test and a post-test or report grader for each of 14 experiments in freshman chemistry laboratory. A record of each student's scores is available to the student and to the instructor. Approximately 1300 students have used the program during the 74-75 school year. Each student interaction requires an average of 22 minutes at a teletype. The total disc requirement for Chemistry programs and records for 900 students occupy approximately 315,000 words of disc storage. Programs are chained together in some cases to provide larger programs. This is transparent to the user.

Additional information regarding this application is available from Dr. J. J. Lagowski, Professor of Chemistry, University of Texas at Austin.

English Composition - Seven instructional modules designed to augment a freshman English course gave students approximately seven hours of tutorial instruction. The students may access the modules as many times as desired and scores are kept for every access. To facilitate program design, a complete record of responses to each question is stored for statistical analysis. These programs are written as a type of program overlay to keep core loading small. During execution a small driver program loads and executes the required overlays. This design appears to improve response time over larger programs chained together; however program transferability is poor

in this format. The programs have been used in regular class assignments by approximately 400 students at publication of this article and continued use is anticipated. Approximately 700,000 words of disc space is required to store the programs.

Additional information is available from Dr. Susan Wittig, Department of English, University of Texas at Austin.

Linguistics - A series of tutorial modules dealing with transformational grammar have been pilot tested. Some of the modules require the student to input a model grammar to be checked for accuracy by the program. This checking requires an extensive amount of string manipulation and the NOVA is not fast enough to provide pedagogically acceptable response time. These modules would need to be revised or moved to a more powerful computer system. Some use was made of graphics terminals to display tree structures depicting grammars.

Additional information may be obtained from Dr. Solveig M.V. Pflueger, Department of Linguistics, University of Texas at Austin.

Physics - Freshman physics students were instructed in the use of the NOVA system as a computational tool to be used throughout their college careers. The students used a teletype terminal and a Time-Shared Peripherals plotter (model TSP-212) to receive graphical output. In a pilot study, approximately 100 students have had very good success with the system. Some of the cited advantages are:

1. Simplicity of BASIC language
2. Simplicity of access to system
3. Ease of file handling
4. High reliability

Additional information may be obtained from Dr. J.D. Gavenda, Professor, Department of Physics, University of Texas at Austin.

Statistics - A series of discovery modules were used with the first course in statistics for Mechanical Engineering. These tutorial programs introduced new concepts for each section of a self-paced course. Use of the programs was optional with the students.

Additional information available from Dr. G. R. Wagner, Department of Mechanical Engineering, University of Texas at Austin.

General Business - Approximately 500 students per semester used the system to learn to write simple business applications type programs. The students had their choice of three input methods; punched card input to batch processing, TAURUS interactive system on CDC 6400 system, or the NOVA time-shared system. In the one controlled test for which data are available, 54 out of 60 students chose the NOVA system. In another test, control groups using both systems indicated that assignments could be done much more quickly on the NOVA system than with batch processing (406 minutes on NOVA versus 722 minutes with batch). A feature of great value to the novice user, such as this group, is syntax checking at input. This gives immediate identification of errors and speeds up program preparation.

A theatre type rear screen projection system was used by the instructor for classroom presentation. The class of approximately 250 students can watch on the large screen as the instructor codes example problems. This has proven to be a valuable teaching tool.

Additional information on the application is available from Dr. Joel Stutz, Department of General Business, University of Texas at Austin.

Home Economics - A series of programs were developed to use a computer controlled slide projector and later a computer controlled Super 8 motion picture projector. These devices were used in

conjunction with a CRT display to depict child development stages. The use of the programs can replace some of the nursery school observation time normally required.

Additional information may be obtained from Dr. Mary Ellen Durrett, Chairman, Department of Home Economics, University of Texas at Austin.

Other Applications - Many other applications were programmed from a variety of games, to design optimization problems by graduate Mechanical Engineering students. Most users are truly surprised with the ease of access to the system, simplicity of programming, the actual computational capacity of the system, and the general overall performance. Many potential users who have grown accustomed to using a large computer are very reluctant to admit that many of their needs could be satisfied by a mini-computer based time-share system. Once students and faculty members begin to use the system they are generally very pleased.

Terminals Used With System

The system has been used with a large variety of terminals at communication speeds from 110 to 1200 baud. Graphics terminal, CRT displays and intercomputer communication was at 1200 baud. High speed impact terminals and CRT displays ran at 300 baud while ordinary teletypes used 110 baud. Two auto-answer telephone devices were operated at either 110 or 300 baud. These devices used an acoustic coupler and a mechanical mechanism to answer the phone and thus did not require ring detect hardware or software in the NOVA nor the data phone service charge from the telephone company.

Site Preparation

As is the case for most mini-computer installation sites, preparations for this system simply meant the designation of a corner of a room as

the site and supplying electrical power and telephone lines. In general there is no greater environmental requirement for the equipment than is required for reasonable personnel comfort. High temperature and humidity conditions will tend to shorten the mean time between failure of most electronic equipment. See Table 1 for site requirements.

Floorspace	150 sq. ft.
Electrical power	2,30A 115VAC 60 cycle single phase
Temperature	Less than 85 F at cabinet intake
Heat dissipation	Approximately 7,200 BTU/hour
Relative humidity	20% to 80%, non-condensing
Communications	Access to telephone lines or direct lines as required

Table 1.
Typical Site Requirements for Mini-Computer Based Time-Share System

Operating Cost Summary

The following is an analysis of operating cost for the Nova Time-Shared System as shown in Figure 2. The final system consists of the following basic components:

Nova 840 Computer with 56K memory
Nova disc 256K word fixed head disc
Diablo disc cartridge unit, 2.5 million word capacity
Paper tape punch and reader
Nova 4063 communication multiplexer, 32 ports

This cost analysis is based upon the assumption that the facility is to be used principally for CAI type applications. CAI applications are characterized by:

1. A high ratio of connect time to CPU utilization.
2. Short CPU burst times per each terminal input.

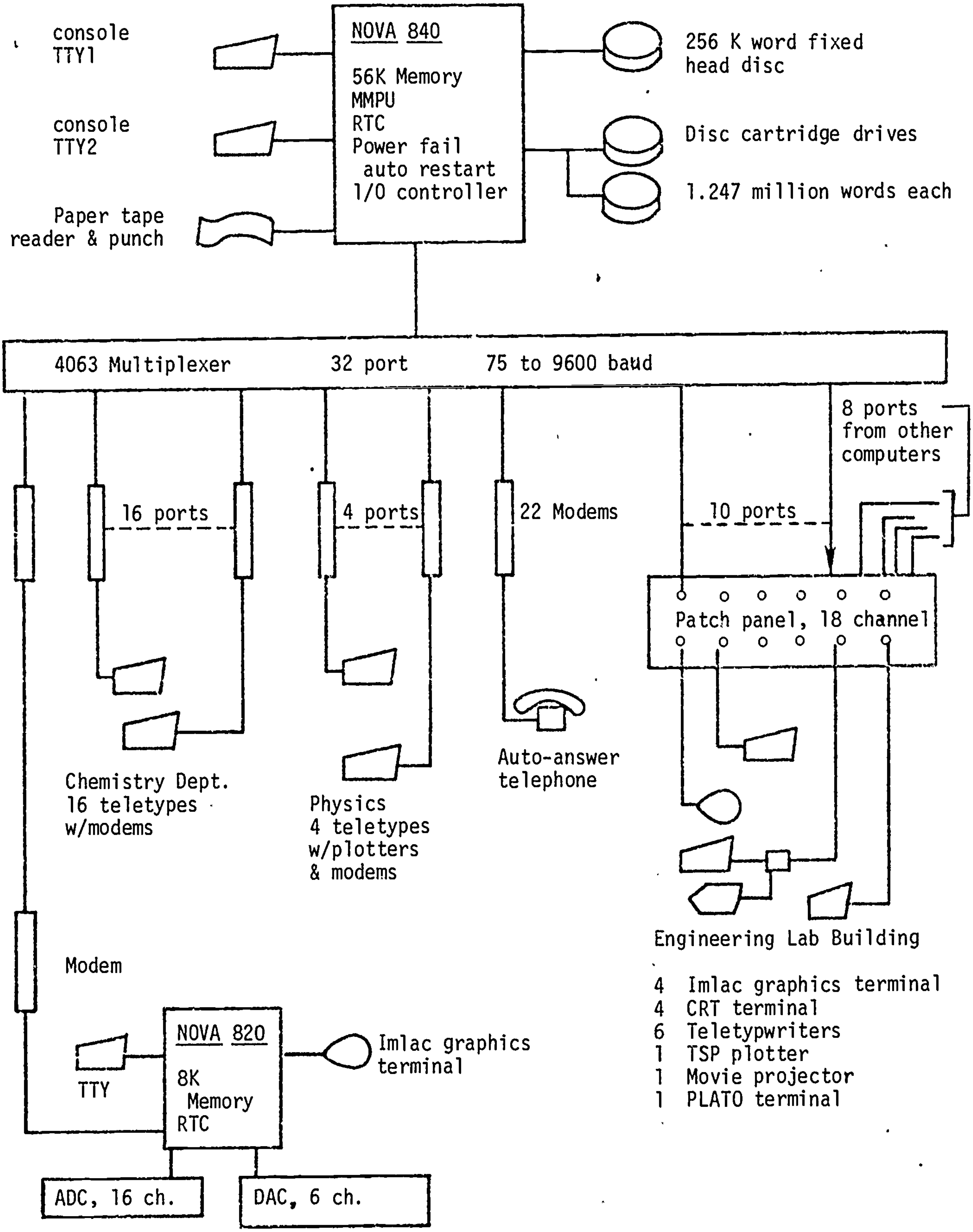

Fig. 2 Schematic diagram of NOVA 840 system as configured Spring Semester 1975.

If the above assumption and characteristics are correct than a fairly uniform mix of jobs will be handled permitting allocation of operating costs to be based upon connect time only. Obviously the true allocation of resources must be based upon many other factors, i.e., CPU time, disc storage, I/O records, etc.

Estimated costs assuming five year amortization period.

A.	Equipment amortization cost			
	1. Computer system configured to support 32 terminals running Extended Basic			
	$70,000/ 5 years	=	$ 14,000	
	2. Modems (22)			
	$6,000/ 5 years	=	1,200	
	3. Installation			
	1. System $2,000/ 5 years		400	
	2. Direct Lines $220/ 5 years		44	
	Total Equipment Cost Per Year			$ 15,644
B.	Operating Expense			
	1. Personnel			
	a. System programmer 1/4 time		$ 5,000	
	b. Operator (2 undergraduate)		10,400	
	2. Maintenance			
	a. Computer system on site contract $650/mo.		7,800	
	b. Modems		516	
	3. Communications			
	22 direct lines @ $1.50/mo.		396	
	Dial service, 2 lines		252	
	4. Supplies		480	
	TOTAL Operating Expense Per Year			$ 24,844
C.	Indirect Cost Per Year 50% of Salaries & Wages $15,400 x .50	=		$ 7,700
D.	Total Cost Per Year			$ 48,188

Consider terminals to be available for use from 8 a.m. to 10 p.m. Monday through Friday and 8 a.m. to 3 p.m. Saturday for total 77 hours per week.

University schedules classes as follows:

Fall semester	15 weeks
Spring semester	15 weeks
Summer	10 weeks
	40 weeks

Total hours available for regularly scheduled instructional use is then: 40 weeks x 77 hours per week or 3080 hours per year. Cost per terminal hour may then be computed based upon the estimated utilization factor.

Utilization	Terminal hours per week 32 terminals	Cost per terminal hour based upon 40 week academic year
100%	2,464	$0.49
75%	1,848	0.65
50%	1,232	0.98
25%	616	1.96

Table 2. Estimated Operating Cost Versus Utilization.

Utilization during the spring '75 semester totaled approximately 10,000 terminal hours which results in a 27% average utilization for the semester. Peak utilization on a weekly basis reached approximately 45% with the highest observed utilization being 94% or 30 active terminals.

Personnel costs listed above provide operators for two full time shifts plus a part-time system programmer. In a typical university environment the duties of the systems programmer would include:

1. System software maintenance including installation of any vendor supplied software modification, troubleshooting and correction, design of locally required modifications, system

generation to accommodate local hardware and software changes.

2. Administration details including account number authorization, budget control, etc.
3. Operator training. Since operators are likely to be students, turnover will be heavy and a continuing training program will be needed.
4. Application program design consultation with authors and student programmers.

The system programmer position could easily be filled by part-time faculty assignment, staff assignment, or graduate student.

The operators' duties will include:

1. Recovery procedures required after each system failure. The required reliability factor dictates that system failures must be kept to a very low frequency and recovery time should be less than ten minutes; therefore, only a very small percentage of operator time should be consumed with recovery procedure
2. General system housekeeping including storage management, account number assignments, accounting updates, etc.
3. Training and self study. Depending upon the expected length of employment and interest, some operators should be encouraged to become proficient in assembly language programming. This will facilitate troubleshooting and modification when necessary.
4. Applications programming will occupy the bulk of the operator's time in most cases. In some cases, in fact, the persons should be hired as applications programmer and simply given enough training to babysit the machine or the program.
5. User consultation can be very time consuming if a large number of students are learning to program on the system.

Undergraduate students are generally the most productive and cost effective persons for these positions. Since most duties are really rather simple, only a minimum of training and experience is necessary.

The maintenence costs indicated above are for an on-site maintenance contract by the manufacturer. Project C-BE did not purchase such a contract for several reasons: (1) high cost, (2) some in-house expertise available, (3) many components are in multiple quantities which allows troubleshooting by exchanging components, (4) manufacturers maintain a local service office so that on-call service was available at reasonable cost and time delay. For the period November '72 through May '75 total maintenance costs from outside vendors have been $1,687 for the 840 time-share system, $1,920 for the 820 data acquisition system in engineering and no expenditure for the 820 system in chemistry. Some minor maintenance has been performed by University eletronics technicians. These costs are very low compared to service contract costs; however, tomorrow may well bring a very large repair bill. Each institution must consider its unique situation and take the necessary action.

Conclusions

Experience acquired during the three years of system operation allows several conclusions to be drawn:

(1) Mini-computer time-share systems can very adequately service many instructional computing requirements in higher education.

(2) For those jobs which can be accommodated by mini-computer systems, service can be provided at low cost with mini-computers.[7] If other computer systems are available, classes of application should be assigned to the appropriate size of computer.

(3) Reliability of a mature system can be very good with availability approaching 100%.

(4) Extended BASIC language can satisfy many computational requirements as well as CAI.

(5) Hardware maintenance costs can be greatly reduced by some in-house capability for trouble-shooting coupled with on-call service from factory trained service engineers. The risk always exists however of having a major problem which will be costly to repair and may cause longer down time than if an on-site maintenance contract from the manufacturer is purchased.

(6) Personnel requirements are very low for operation of the system. The system will operate completely unattended except for the rare occasions when problems occur. Any personnel assigned to the system will have most of their time available to do other things, such as applications programming.

(7) The mini-computer operating system is relatively simple and may be learned and maintained by interested students. Computer Science students will find the system very interesting and after a year or two of exposure to it will be able to make minor changes and error corrections. Since students are transients there needs to be some qualified permanent person available to supervise them. This can be provided by a faculty or staff member on a part time basis.

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APPENDIX A

Appendix A. User Subroutines

Extended BASIC as supplied by Data General Corporation allows the addition of user supplied assembly language subroutines. Subroutines can be designed to satisfy an infinite variety of special requirements and are commonly used to service special devices such as analog to digital, perform special operations which BASIC will not do or which are slow or cumbersome in BASIC, etc.

User subroutines are called from a BASIC program by the calling sequence:

In CALL N, A_1, A_2, ..., A_n

where ln is line number

N is subroutine number

A_1 - A_n are arguments to be passed to subroutine

n must be ≤ 8

The following is brief user documentation for the subroutines installed in the system.

```
;***********************************************************************
;
; CALL 5
;
; CALLING SEQUENCE:  CALL 5, I$
;      WHERE
;        I$ WILL BE RETURNED WITH THE STRING
;        INPUT AT A TERMINAL INCLUDING
;        COMMAS AND LEADING BLANKS.
;        I$ MAY NOT BE SUBSCRIPTED.
;        THERE IS NO PROMPT.  THERE IS NO CARRIAGE
;        RETURN FOLLOWING THE CALL.
;
;***********************************************************************
;***********************************************************************
;
;  CALL 8
;
; CALLING SEQUENCE:  CALL 8, K$
;      WHERE
;        K$ IS A BASIC COMMAND LINE TO BE ENTERED
;        INTO THE PROGRAM.
;        (E.G. K$="150 LET N=COS(X+Y)<13>")
;
;***********************************************************************
;***********************************************************************
;
; CALL 13
;
; CALLING SEQUENCE:  CALL 13,X,A$
;      WHERE
;        A) A$ IS A NON-NULL VARIABLE, WHICH MAY BE SUBSCRIPTED.
;        B) ORDINARILY 0<=X<=254.
;        C) X IS A VARIABLE OR A NUMERIC EXPRESSION.
;
;      ADD 1 TO BINARY REPRESENTATION OF FLOATING POINT NUMBER X
;      AND PUT THE LOW ORDER 8 BITS INTO 1ST CHARACTER OF A$.
;
;***********************************************************************
;***********************************************************************
;
; CALL 31
;
; CALLING SEQUENCE:  CALL 31,A$,X
;      WHERE
;        A) A$ IS A VARIABLE WHICH MAY BE SUBSCRIPTED
;        B) X IS ASSIGNED
;
;      SUBTRACT 1 FROM ASCII REPRESENTATION OF 1ST
;      CHARACTER IN A$ AND CONVERT THAT INTO A FLOATING
;      POINT NUMBER  -1<=X<=254.
;***********************************************************************
```

```
;*********************************************************************
;
; CALL 21
;
; CALLING SEQUENCE: CALL 21,S$,N
;       WHERE
;         A) A STRING OF DECIMAL DIGITS IN S$ WILL BE
;            CONVERTED INTO A FLOATING POINT NUMBER IN N.  TERMINATOR
;             IN S$ IS ANY CHARACTER WHICH IS NOT LEGAL IN
;            A DECIMAL NUMBER.
;         B) S$ IS A VARIABLE WHICH MAY BE SUBSCRIPTED OR A CONSTANT.
;          C) N MUST BE ASSIGNED.
;
;*********************************************************************
;*********************************************************************
;
; CALLS 6 AND 7
;
; CALLING SEQUENCE:  CALL 6,A,B
;                    CALL 7,C,D
;       WHERE
;         A IS RETURNED WITH THE OLD PAGE SIZE
;         C IS RETURNED WITH THE OLD TAB SIZE
;         B IS THE NEW PAGE SIZE
;         D IS THE NEW TAB SIZE
;         (B AND D MAY BE EITHER CONSTANT OR VARIABLE)
;
;*********************************************************************
;*********************************************************************
;
; CALL 12
;
; CALLING SEQUENCE:  CALL 12,N,S$
;       WHERE
;         DIM(S$)>=13, S$ NOT SUBSCRIPTED
;         N IS A VARIABLE OR NUMERIC EXPRESSION WHICH
;         WILL BE CONVERTED INTO A STRING
;         OF DECIMAL DIGITS IN S$
;
;*********************************************************************
;*********************************************************************
;
; CALL 20
;
; CALLING SEQUENCE:  CALL 20,A$
;       WHERE
;         A$ (MUST BE A VARIABLE) IS THE STRING WHICH
;         WILL BE RETURNED WITH USER'S ACCOUNT NUMBER.
;         DIM(A$)>=4 AND IT MAY NOT BE SUBSCRIPTED.
;
;*********************************************************************
;*********************************************************************
;
; CALL 99
;
; CALLING SEQUENCE:  CALL 99,U
;       WHERE
;         U (MUST BE A VARIABLE) WILL BE RETURNED WITH
;         THE TOTAL NUMBER OF USERS ON THE SYSTEM AT
;         THE TIME OF THE CALL.
;
;*********************************************************************
END AT 9999
```

APPENDIX B

Appendix B. Usage Accounting System

The Project C-BE generated usage accounting system serves several functions: (1) provides a means of easily assigning account numbers to users, (2) processes the raw accounting file (BASIC.AF) into usage records, (3) generates password file (BASIC.ID) from list of authorized users, and (4) generates usage reports.

The system consists of a number of programs as listed below and briefly documented in the following pages.

"AE"	Account editor
"IDGEN"	Creates block accounts
"UPDATE"	Usage information processor
"RENEW"	I D file generator
"PORT"	Generates usage reports by port, hour, etc.
"REPORT"	Generates usage report by account number

AE

"AE" is the account editor for the system. For each account ID in the system there is one record in the file "ACCNTS" containing the following information:

Account ID
Account Password
Directory
Start-up Program
Name of Account Holder
Year-to-date and Monthly:
- Charges
- Line Time
- CPU Usage
- I/O Usage

Monetary Allocation
Expiration Date

"AE" is used to create, access, alter, and delete these records. Note that "YEAR" and "MONTH" can be any period and subperiod thereof. Available commands for the editor are listed at run time and are EXAMINE, UPDATE, ADD, DELETE, NUMBER, STOP, and ZERO.

The "EXAMINE" command will search for either a single account ID (the first four characters) or it can perform an entire string search of the account ID and password, directory, start-up program, and name throughout the entire account file. Naturally, the string search will consume far more time than the account search. Therefore, a string search is accomplished by typing "FULL" in response to the query "ACCOUNT or FULL SEARCH?" During a string search, should a match be found, the account record will be displayed and the prompt "STOP?" will be displayed. A response of yes will cease the search. Any other response, including a "CR" will continue the search for more matches. To exit from the "EXAMINE" mode, a "CR" should be struck in response to "ACCOUNT or FULL SEARCH?"

The "UPDATE" command will search for a single account ID and then display editable information from the account record. Should a change be desired, the information should be retyped after display. Otherwise, the "CR" should be struck. Note that to delete the start-up program, it is necessary to type a slash. This eliminates the start-up program at sign-on time. To exit from the "UPDATE" mode, a "CR" should be struck in response to "GIVE ACCOUNT NUMBER."

The "ADD" command is used to add new accounts to the system. Proper response to the query "ENTER ACCOUNT STEM:" is either a four charater account ID or a two letter stem. A four character ID consists of two alphabetic characters followed by two numeric characters. To enter a number of sequential accounts, it is usually desirable to give only the two letter stem. The editor will then query "NUMBER OF ACCOUNT TO ADD?" and "COMMON OR PRIVATE DIRECTORIES?" if the response is "COMMON", the query "GIVE COMMON DIRECTORY:" will be displayed. The disk device must be included in the response (e.g. "DPO:WAG"). If the response is "PRIVATE", the query "WHAT DISK?" will be displayed. Proper responses are usually "DPO" or "DP1". The name given to the private directory will be identical to the account ID, e.g., DPO:AG03. Accounts will then be added sequentially starting immediately after the last account in the current stem, e.g., if PH01 through PH30 and PH40-PH60 already exist and 10 new accounts are being added, they will be PH71-PH80. If the stem is new, numbering starts with 01. Entering a four character account ID causes that account to be added provided it doesn't already exist.

The "DELETE" command is used to remove accounts from the system. The query "BLOCK OR MISCELLANEOUS ACCOUNT?" will be displayed. Response will then prompt "ENTER DELIMITERS, SEPARATE WITH COMMA." All accounts that are alphabetically within the delimiters will be deleted. For example:

To delete account NC05, type "NC05, NC05"

To delete all "WA" accounts, type "WA00, WA99"

To exit from the "DELETE" command, type a "CR" to the initial query.

The "NUMBER" command will give the total number of accounts in the system, both miscellaneous and block.

The "ZERO" command is used to initialize to zero either: (1) the month-to-date usage figures for all accounts, miscellaneous and block, or (2) the year-to-date usage figures for all accounts, or (3) both.

The "STOP" command is used to exit from the editor. Exiting without typing "STOP" is not recommended.

"AE" makes use of several auxiliary files. "AD", "AD2", "EX", "DEL", "UPD", "NUM", and "ZER" are overlay files entered by "AE" to implement the relevant command. "TABLE" is a data file which holds a string of all account ID's in alphabetic order. "TWRITE" recreates "TABLE" from "ACCNTS" and should be used only if "TABLE" is destroyed. "SEARCH" is a subroutine for searching "TABLE". "STRING" holds a string of characters having ASCII codes from 0 to 99, and is used to convert numbers into characters and vice versa.

IDGEN

"IDGEN" is used to create a series of block accounts. Normally, not less than 100 accounts should be reserved in a particular block stem. (A block stem is one letter.) The account system can handle a maximum of eight block stems. These stems will reserve an entire letter for the stem and thereafter no miscellaneous accounts may be added with that beginning letter. Attempts to do so will result in an error message. "IDGEN" will initially prompt "APPEND OR RENEW?". A response of "RENEW" will produce the following queries: "ARE YOU SURE?" and "THIS PROCEDURE WILL WIPE (AND I MEAN WIPE) THE ENTIRE (AND I MEAN ENTIRE) ACCOUNT FILE. ARE YOU STILL SURE?". A response of anything other than "YES" will terminate the renew. Normally, this procedure is used only to initialize the account file (e.g. at the beginning of the semester).

An "APPEND" response will prompt "NEW BLOCK STEM (ONE LETTER):". The letter stem must be unique in that no other accounts may already

exist with that first letter. An acceptable response will prompt the following:

NUMBER OF ACCOUNT:
COMMON OR PRIVATE DIRECTORIES:
ALLOCATION (EACH ACCOUNT):
ENTER EXPIRATION DATE:

A reply of "common" will require the specification of that directory. A reply of "PRIVATE" will result in a request for the disk device and will then assign the same directory name "XSL" to all block accounts between SL00 and SL99, e.g., DP0:XBA for BA00 - BA99, DP0:XBB for BB00 - BB99, and DP0:XBC for BC00 -BC99 in the event 300 block accounts are created with stem "B". (NOTE: We have modified BASIC so that for any directory whose name begins with "X" (e.g., DP0:XBA) the first two characters of each filename are the two numbers in the account ID of its user. Thus 100 users can have private files on the same directory, e.g., if account ID's BB00 through BB99 all have directory DP0:XBB, 43JANE is accessible only by BB43 and 62JANE is accessible only by BB62. Both users refer to their file by JANE. If BB37 issues a FILES command, he/she sees only those files on DP0:XBB which begin with "37".) All accounts that are generated will be displayed along with their random passwords. Note that the total number of all block accounts may not exceed 9000. To terminate "EDGEN", strike the "CR" in response to the initial query.

UPDATE

"UPDATE" is the accounting system maintenance program. It will transfer the accounting information that "BASIC" writes to the file "BASIC.AF" into the account file "ACCNTS" and "SYSDAT". Normally, this program should be run once a day. NOTE: "UPDATE" will chain to "RENEW". "UPDATE" is executed via a 'RUN "UPDATE"' command.

RENEW

"RENEW" will update the "BASIC" file "BASIC.ID" based on the current information in "ACCNTS". Accounts which have exceeded their allocation

or have existed beyond their expiration date will not be written to "BASIC.ID". Instead, they will be displayed at the terminal with appropriate messages. "RENEW" is executed via a 'RUN "RENEW"' command.

PORT

"PORT" generates usage reports for year-total and period-to-date in line hours and number of jobs. These data are reported as a function of: (1) Port number (ports -1 through 31), (2) day of week, (3) hour of the day, and (4) each day since beginning of current period. A period begins when the "month to date" usage information in "ACCNTS" is reinitialized by means of the "ZERO" command in "AE". "PORT" makes use of data stored by "UPDATE" kept in records 0-3 of file "ACCNTS" and in "SYSDAT". "PORT" chains to "REPORT".

REPORT

"REPORT" is automatically chained to by "PORT" or may be executed separately. The program is designed to print usage reports for all accounts authorized by the file "ACCNTS". A full report would list all usage records for each user, totals for each group of users having common account number stems, and finally, total system usage data for the accounting year and period.

The program is self coaching and has the following commands:

A - ALL ACCOUNTS
B - BLOCK ACCOUNTS
E - END
M - MISCELLANEOUS ACCOUNTS
O - SET OUTPUT TYPE (NORMAL, CONDENSED, JUST TOTALS)
R - SET REPORT TYPE (MONTHLY, YEARLY, OR FULL)
S - SINGLE MISCELLANEOUS ACCOUNTS

If further information is required by a command the program will request it.

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